Composition and bioavailability of DOC across a rural-urban gradient

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A thesis submitted for the degree of
Doctor of Philosophy

April 2006

Contents

Summary

A great deal of attention has been focused on the effects of changes in land use on the physical and chemical conditions of streams and riparian zones. There is also currently substantial momentum and effort directed at restoring these areas. However, there is a distinct lack of understanding of not only the processes that occur in natural systems, but also the impact that changes in land use have actually had on those systems, and of how the "restored" system will function post intervention. The objective of this thesis was to examine the impact of urbanisation on the composition, and bioavailability and retention of organic carbon in streams.

Changes in composition, and bioavailability of organic carbon in stream water were investigated across rural-urban gradients in sub-catchments of the Torrens River, a mediterranean catchment in southern Australia. The influence of land use on the relative proportion of particulate and dissolved organic carbon, and the importance of different size fractions of the total organic carbon pool in driving biochemical oxygen demand (B.O.D.$_5$) was assessed under base flow and storm flow conditions. Despite an expectation that an increased proportion of oxygen demanding material would be comprised of particulate material in the urbanised catchments, the results demonstrate that dissolved organic carbon comprises a substantial component of the organic carbon pool in both the rural (83%) and urban (89%) sites. Furthermore, although particulate material actually represents a higher proportion of oxygen demanding material in the rural sites (23%) than in the urban sites (4%), the difference is not statistically significant.

Bioassays performed on stream water samples demonstrated that DOC from the urbanised streams was more bioavailable than in the rural streams; the DOC in the urban streams exerted an oxygen demand per unit organic carbon 2.75 times higher than the rural streams. Furthermore, the DOC in samples from the urban streams was depleted in an exponential manner. In contrast, DOC was depleted in a slow, linear manner in samples from the rural streams. Ion-exchange fractionation of the samples revealed significant differences in urban and rural stream water DOC that demonstrates that urbanisation induces a substantial shift away from the naturally occurring range of DOC compounds (e.g. humic and fulvic acids, carbohydrates, oligosaccharides, polysaccharides) towards synthetic compounds (e.g. synthetic detergents, hydrocarbons, pesticides) which is correlated with an increase in BOD:DOC ratios. However, an assessment of the impact of inflowing stormwater on

DOC dynamics and water quality in Torrens Lake (a shallow urban weir pool) demonstrated that the DOC fractions most readily depleted and therefore most likely to be the most problematic, oxygen demanding organic compounds were the aquatic humic substances (e.g. humic and fulvic acids), and hydrophilic acids (e.g. fatty acids, sugar acids, hydroxyl acids).

The shift from native tree species to introduced deciduous species that commonly occurs in urbanised areas may have a series of profound effects on ecosystem function and stability. Bioassays and ion-exchange fractionation revealed that DOC released from the introduced species (English elm, London plane tree, white poplar and introduced grasses) has a distinctly different composition than that leached from a common native species (river red gum). Observed imbalances in DOC:FRP ratios and DOC metabolism kinetics between the different species indicates that changes in dominant vegetation may have serious implications on biogeochemical cycles. Furthermore, the rapid release of DOC from all litter types tested indicates that if gross pollutant traps (designed and installed to protect streams from pollutants such as leaf litter) are not cleared for 48-72 hours after the onset of rain, the majority of water soluble, oxygen demanding material will still enter the receiving water.

Sediment core studies revealed that although undisturbed and resuspended sediments generate a substantial oxygen debt (0.8 and 1.4 g O_2 m^{-2} day^{-1} respectively), external loading of oxygen demanding organic material is responsible for the episodic deoxygenation of the water column that is often observed in Torrens Lake following rain events. Furthermore, although internal loading of filterable reactive phosphorus (FRP) from sediments (17mg FRP m^{-2} day^{-1}) represents a major source of bioavailable P that is potentially available to support algal blooms, external loading from inflowing stormwater (40μg FRP L^{-1}) continues to represent a major management concern and impediment to controlling the episodic nuisance and harmful algal blooms experienced in the Torrens Lake.

Urbanisation induced changes to the ability of a stream to retain DOC was assessed in three contrasting stream reaches; a reach that has retained a complex geophysical channel structure, a reach that has been converted to an open concrete channel, and a reach that has been converted to an underground concrete channel. DOC uptake kinetics in the degraded reach were characterised by long retention times, increased dilution, and comparatively short uptake lengths (79.9 ±7.4m). In comparison, the heavily engineered concrete channel was characterised by high water velocities and long uptake lengths (273.9±43.8m). In contrast to the engineered reaches, the degraded reach maintained a relatively stable expected peak DOC concentration, uptake length and percent uptake, indicating that restoring stream complexity in urbanised streams by removal of concrete channels and reconstruction of natural meandering flow paths has a major role for improving the buffering capacity of urban streams.